U. S. DEPARTMENT OF LABOR
BUREAU OF LABOR STATISTICS
ROYAL MEEKER, Commissioner

BULLETIN OF THE UNITED STATES BUREAU OF LABOR STATISTICS
WHOLE NUMBER 165

INDUSTRIAL ACCIDENTS AND HYGIENE SERIES: No. 8

LEAD POISONING IN THE MANUFACTURE OF STORAGE BATTERIES

DECEMBER 15, 1914

WASHINGTON
GOVERNMENT PRINTING OFFICE
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LEAD POISONING IN THE MANUFACTURE OF STORAGE BATTERIES.

BY ALICE HAMILTON, M. A., M. D.

INTRODUCTION.

The making of storage batteries, or electric accumulators, as they are called in every country except our own, is increasing in extent and importance everywhere. It is regarded as a very dangerous lead trade and the Governments of Great Britain and other European countries have made strict regulations as to the sanitation of places in which such work is done and as to the methods to be employed in them, since experience has shown that in the absence of regulations lead poisoning among the workers is a very serious evil.

In the United States there are five large factories where storage batteries are made, one in Cleveland, Ohio; one in Depew, N. Y.; one in Suspension Bridge, N. Y.; and two in Philadelphia, Pa. A great many smaller plants, employing from 5 to 15 men each, are scattered throughout the country, and many automobile factories now have their own storage-battery departments. There are also establishments where no new batteries are made but where old ones are reassembled and recharged. Railway companies usually have small plants for recharging the batteries used for train lighting. As a rule the smaller factories are rather neglected and dirty, more so than are the larger ones. The largest factory in the country has branches in several cities to which are shipped the plates ready for use and these are then assembled into batteries in the branch establishments.

A storage battery is described as a collection of secondary cells, or accumulators, which, when once charged by an electric current, may be used for some time as the source of electricity.

The original type of storage battery, known as the Planté, consists of lead plates, which are usually corrugated or perforated to offer a larger surface for the chemical action of the charging current. The Faure cell was constructed with the purpose of hastening these

chemical changes. Faure plates are covered with a paste of lead oxides, the positive plate with red lead or a mixture of red lead and litharge (rarely with pure litharge) and the negative plate usually with litharge. Sometimes a Faure negative is paired with a Planté positive plate. Both Planté and Faure plates are "formed" by the passage of an electric current, the effect of which is to change the metallic lead of the Planté positive plate and the lower oxides of the Faure positive plate to a higher oxide of lead, the brown peroxide, while at the same time the surface of the negative plate is reduced to spongy metallic lead. During the discharge of the electric current the reverse takes place, and a certain amount of lead sulphate is formed also, so that an old storage-battery plate is covered with a mixture of the sulphate and the lower oxides.

For many years such cells were the only ones used for storage batteries, but of late the nickel-iron battery of Edison (the so-called alkaline battery) has been introduced and is said to be coming rapidly into general use. In this battery the positive plate consists of perforated steel tubes filled with nickel hydrate, the negative of perforated steel pockets filled with iron oxide. They are immersed in a bath of potassium hydroxide and charged, the nickel in the positive plate being changed to black nickel oxide and the iron oxide of the negative to spongy iron.

Edison batteries are, therefore, free from lead, but the Planté and Faure are lead batteries and their manufacture involves the exposure of workmen to the dangers of lead poisoning. There are many processes in the making of these batteries which are attended with the formation of lead fumes or metallic lead dust or lead oxide dust and in which the workman's hands and clothes become covered with these substances. First, there is the casting or molding of the "grid," or plate, from molten lead which has usually a small percentage of antimony added. For Planté cells the grid is cast in ridges and furrows, or it may have roughened markings on the surface, or spaces filled with rosettes of lead ribbon. Faure grids are made in such shape as to hold large quantities of lead oxide paste. The grid when it comes from the mold is straightened and the irregular edges are trimmed smooth by hand or by machine. Then the grids for the Faure batteries must be covered with paste, and for this purpose red lead and litharge are weighed and mixed dry and then worked up with a liquid, usually dilute sulphuric acid. This also may be done either mechanically or by hand. The resulting paste is rubbed and pressed into the interstices of the leaden grids and the pasted plates are dried, assembled in pairs of positive and negative, immersed in dilute sulphuric acid, and subjected to the action of an electric current. This is known as "forming," and the formed

plates are then washed clean of acid, dried, and made up into battery cells. To do this the pairs of plates must be assembled into large or small groups and bound together by means of pure lead which is melted with an oxyhydrogen flame, a process called lead burning. Then another electric current is passed through the cells to "charge" them, and finally the men known as the "finishers" place them in receptacles of acid and fasten on the outer connectors with pure molten lead.

This is a general description of the work in a storage-battery factory, but it will be necessary to take it up more in detail, for there are many ways of carrying out the different processes, some of which are more dangerous than others. In the following sections the processes are given in their logical sequence, not in the order of their occurrence as one passes from room to room in any one factory. Often in the smaller plants all the work is carried on in one room, but in the five largest the different steps are separated to a certain extent. Forming and charging are always done in special rooms in these larger factories; weighing and mixing oxides and compounding paste are usually separated from the rest of the work; this is sometimes true of pasting; and casting and trimming the grids and assembling and lead burning the plates are generally carried on in one or more large rooms, together with the making of Planté plates and the final "finishing."

PROCESSES IN THE MAKING OF STORAGE BATTERIES.

CASTING OR MOLDING.

There has been a good deal of controversy, especially among the Germans, over the presence of lead fumes in the air around the casting kettle of a storage-battery plant. Wutzdorf[1] holds that fumes escape in the course of the work of casting grids even when the lead is not much above 450° C. (842° F.). Wagener[2] also believes that fumes arise from the melting pot, and he calls attention to the appearance of blue clouds whenever the workman stirs the contents of the pot. The tests made by the factory inspectors in the Hagen factory, where the kettles are furnished with hoods, showed that even with that protection lead escaped into the air, for damp filter paper suspended above the casting benches showed the presence of particles of lead. British factory inspectors assume that there may be an escape of fumes from any molten lead which is exposed to the air, and they insist on precautions being taken accordingly.

In American factories the lead used in casting is supposed to be decidedly below the fuming point, but if one watches the work of a

[1] Arbeiten aus dem kaiserlichen Gesundheitsamte, 1898, vol. 15, pp. 154–170.
[2] Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, 1902, vol. 34, pp. 529–578.

molder one can see that though there are no visible fumes as long as the lead is undisturbed there are quite perceptible bluish fumes when the dross is skimmed or the lead ladled out. These fumes are in all probability the lower oxides of lead in a state of very fine division and are therefore very poisonous. The analyses of air made for the New York Factory Investigating Commission[1] by Dr. C. T. Graham Rogers and John Vogt, B. S., show that in the storage-battery factories in that State there is sometimes lead in the air around the melting pot. They found 3.4 milligrams of lead in 1 cubic meter of air in the casting room of a plant which had no exhaust over the pots and 1 milligram in a second place where the kettles were well hooded. As an adult breathes about 4.5 cubic meters of air during 10 hours, this would indicate that a man in the first factory might breathe 15.3 milligrams of lead during his day's work and a man in the second 4.5 milligrams, provided this contamination of the air were constant and not accidental. In that case a man employed in the casting room of the first factory would run serious risk of lead poisoning, if it is true, as Teleky says,[2] that a daily dose of 10 milligrams for several weeks may lead to severe acute poisoning.

The molder stands close to the kettle, skimming dross and ladling lead into the molds. The dross he usually throws on the floor beside the kettle and walks to and fro over it as he works, grinding some of it into dust, which contaminates the air.

The accompanying illustrations show how conditions may vary between casting rooms. The first (pl. 1) represents a casting room in one of the five large factories visited. The kettles are hooded, the hoods being connected with flues which carry off the fumes from the molten lead. The floor is reasonably clean, and the room displays an evident intention to reduce the inevitable dangers of the work to a minimum. In the second (pl. 2) conditions are much less satisfactory. The kettle is unhooded, the open window beside it being relied upon to carry off the fumes. The dross and lead scraps on the floor are much in evidence. It is easy to see how as the men go about their work this lead refuse is ground into the wooden flooring until cleaning the latter in any satisfactory fashion is a practical impossibility.

The danger in the casting room is in proportion to the number of kettles, the presence or absence of hoods with exhausts over the kettles, the degree of care which is used in handling the dross, and the separation of this work from other dangerous processes, for, in many factories, pasted plates are handled in this room and the dust of the dry oxide paste is thus added to the metallic dust. Work in the casting room is sometimes made very disagreeable by the

[1] Second report of the New York State Factory Investigating Commission, vol. 2, pp. 1129 and 1131.

[2] Protokoll der Sitzung des grossen Rates des Instituts für Gewerbehygiene, 1912, A. Seydel, Berlin, p. 15.

PLATE 1.—CASTING ROOM IN LARGE AMERICAN FACTORY.

Casting room, showing melting pots with hoods which are connected with a large flue and which serve to carry off the fumes from the molten lead. The large supply pipe for this flue may be seen in the far corner of the room.

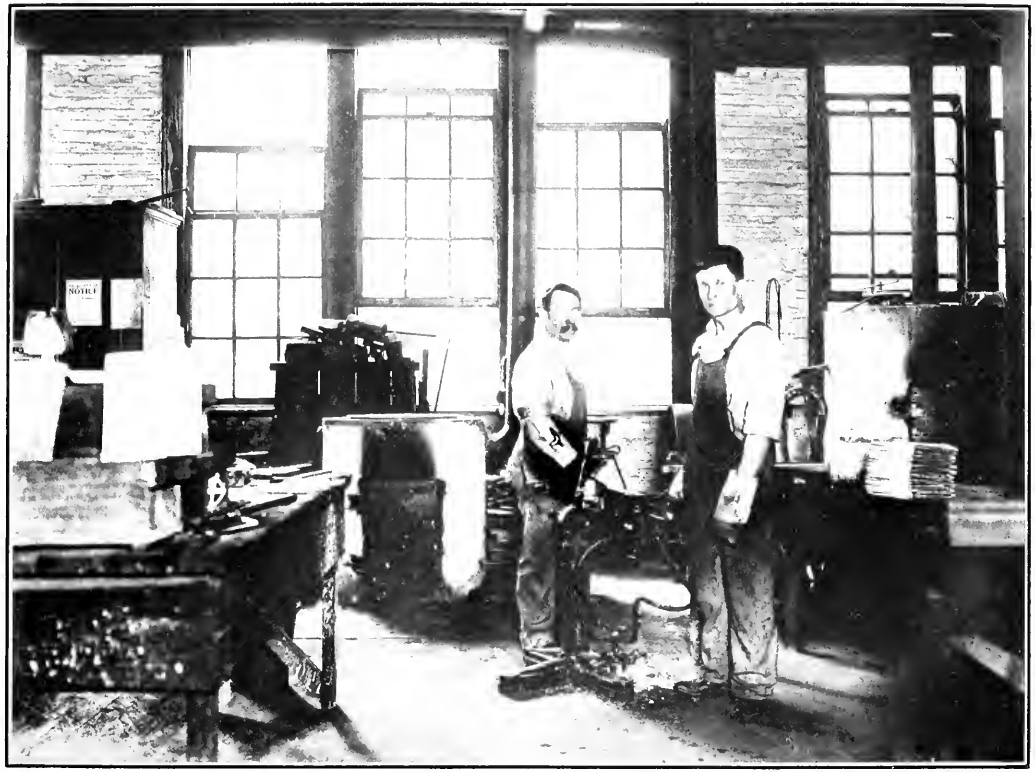

PLATE 2.—CASTING GRIDS BY HAND.

methods used in preparing the molds to receive the molten lead. For instance, in one plant visited the molds are dusted with very finely ground soapstone, used in such quantities that the room looks like a flour mill, while the men are powdered like millers. In another jets of smoky acetylene gas are passed over the molds till a layer of carbon has formed, and the result is an atmosphere black with smoke.

Wutzdorf [1] draws attention to the danger of arsenic in the fumes from the melting pots in the casting room, for the lead that is used may contain an appreciable quantity of arsenic. He quotes some analyses made by Fischer,[2] which show that the arsenic present in hard or antimonial lead may run from 0.16 to 7.9 per cent. A smelting expert in the United States is authority for the statement that no antimonial lead in this country is quite free from arsenic.

TRIMMING GRIDS.

For convenience in handling, grids are often cast in pairs and then sawn apart by a machine which may have no protection or may be furnished with a glass or celluloid screen to keep the particles from flying in the workman's face. The edge of the grid must be smoothed and the superfluous lead cut or filed away, either by hand or machinery. In some places this work is very slight in amount, but in others there is a great deal of it. For instance, one plant was visited in which 16 boys were trimming edges with big knives, while in another plant almost as large, there were only two hand trimmers; the rest of the work was done by machinery and, since the grids were cast with clean edges, not much of it was necessary.

There is a handle on the grid which projects from the battery and forms part of the connecting system, the leaden connectors being fastened on here. This is called the "lug," and in the case of small grids the lug is cast in one piece with the body of the grid, but in the case of large grids it must be burned on to the body. The work of lug burning is also done in the casting room.

The casting of Planté plates differs somewhat from the method just described. Usually lead from a large kettle is run into a great flat mold and the resulting thick sheet of pure lead is rolled out by machinery till it is very thin. Plates are cut from this sheet and ridges and furrows are then cut into them by machinery. This is called "spinning" or "swedging" and is done with an abundance of oil or water to keep down the heat; incidentally the dust also is kept down. Another common variety of Planté plate is the Manchester, which consists of a frame of antimonial lead with interstices into which rosettes of lead ribbon are pressed.

[1] Arbeiten aus dem kaiserlichen Gesundheitsamte, 1898, vol. 15, pp. 160–161.

[2] See Handbuch der chemischen Technologie, von Dr. Ferdinand Fischer, Leipzig, 1893, S. 272.

The men who handle the Planté plates are exposed to oxide dust to a certain extent after the plate has been formed.

MIXING THE OXIDES FOR FAURE PLATES.

Up to this point the workmen have been exposed only to metallic dust and possibly to fumes from the kettles, provided the processes described have been carried on in rooms separate from those in which operations involving the making or handling of paste or pasted plates are performed.

The trimmed grids for Faure cells must next be covered with a paste, the composition of which is a trade secret, but the essential elements of which are the oxides of lead. It is generally said that dilute sulphuric acid is used for moistening the oxides, but some paste rooms reek with ammonia fumes, showing that ammonia may enter into the composition of the paste.

Usually, mixing the dry oxides for the paste is done with some precaution against dust. Plate 3 is an illustration of the mixing of oxides by hand without precautions. In one plant the weighing, dumping, and mixing all go on under cover and are controlled by a workman who stands outside the inclosure and works through a window in the wall. In another of the larger plants there is a similar method of dumping the oxides under cover, but it is so carelessly managed that though the room is new and the mixer well covered, the place is full of oxide dust. In a third the work is done in the open but carefully and with exhausts over scales and mixers, so that the room is very clean.

In a fourth large plant the mixing is carried on at one end of the pasting room. There is no exhaust over scales or mixer and the litharge or red lead is simply scooped up from the kegs and dropped into the scales, which are then emptied into the mixer. At the time this place was visited a workman was engaged in mixing oxides, and clouds of yellow dust were perceptible. In one of the smaller plants also the oxides were being weighed on unprotected scales and mixed in an open chaser directly beside the pasting table.

The accompanying illustration (pl. 4) shows the process of mixing paste by hand. The mixing takes place under glass cabinets connected with a large flue, the exhaust in which is supposed to carry off the dust. Nevertheless a coating of dust is plainly visible on the platform on which the mixers stand and on the benches and utensils near them.

MAKING THE PASTE.

By far the safest way is to have all the paste made up in a special room and given to the men who then apply it to the grids. In this way only a few men come in contact with the dry oxides. This method is followed in three of the five largest plants, but in the other

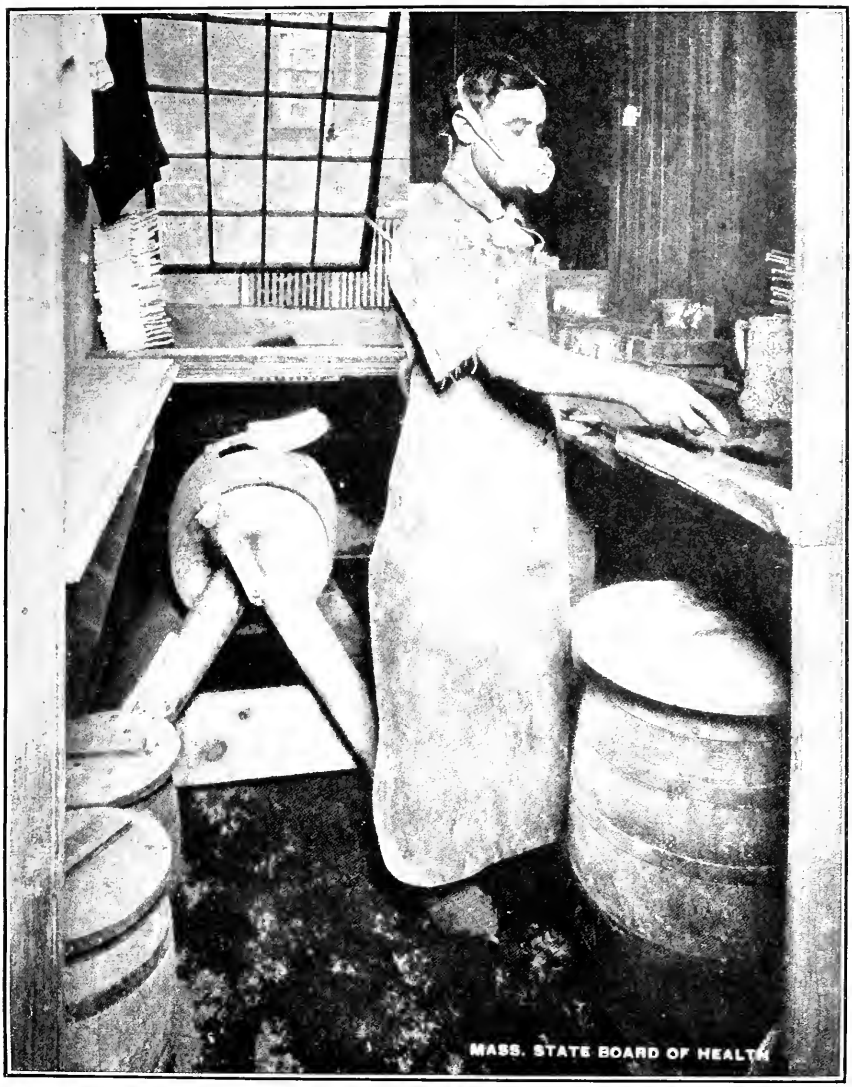

PLATE 3.—MIXING LEAD OXIDES.

The work is done partly by hand, partly in a primitive, churn-like machine. There is no device for removal of the dust which is formed in weighing, in filling the mixer, and in emptying the mixer.

PLATE 4.—PASTE MIXING BY HAND.

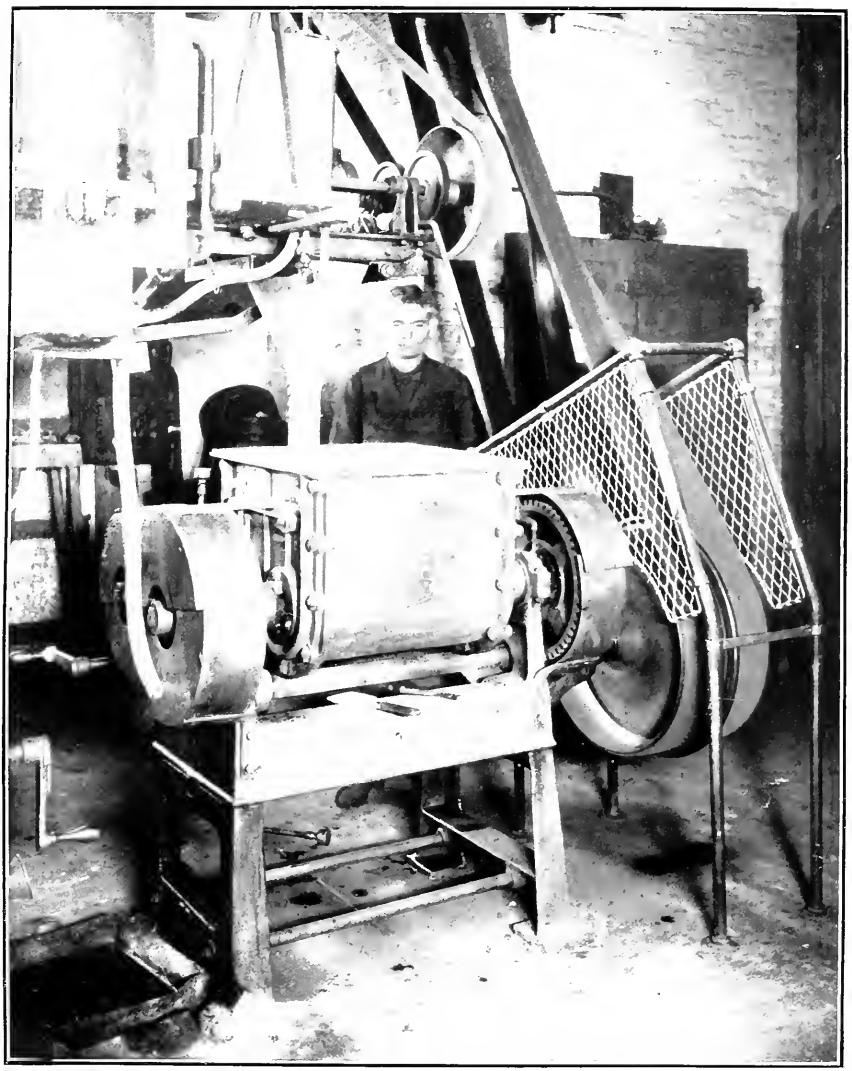

PLATE 5.—PASTE MIXING BY MACHINE WITH DUST-PROOF FUNNEL.

The oxides are admitted from an overhead bin and mixed without necessitating opening the machine.

two the dry oxides are made into paste in the pasting room. In one of the latter four or six men make up the powder into paste by hand, working at a table with a glass case and an exhaust. At the time this place was visited the floor near the paste-mixing table was covered thickly with scarlet dust and the mixers' overalls and shoes were scarlet. Three cases of lead poisoning were found which had been contracted at this table during 1913. The dust is also a menace to the pasters who work in the same room. The other plant has an even worse method, for here the dry oxides are weighed in open scales in quantities for the pasters, each of whom must make up his own paste. There are no exhausts at these pasting tables.

In the three plants where the paste is made for the men, paste mixing is done in a special room. Bread-kneading machines are used for this purpose in one (see pl. 5), and in another the paste is mixed in large mortars beside each of which is an exhaust. Neither of these plants is above criticism in the conduct of this part of the work, for the rooms are far dustier than they should be and one is in an extremely neglected condition. The third plant has a fairly clean mixing room with a cement floor which can be flushed with water, but the man who makes the litharge paste has a dangerous habit of throwing handfuls of dry litharge over the tray which is waiting for the paste, as a baker would flour a pan to keep the dough from sticking.

Wagener [1] says that when the making of paste and the pasting of plates were carried on in the same room in the Hagen factory, 20 out of 27 men in that room had lead poisoning, but after the two processes were separated only 10 out of the same number were poisoned. He also gives the results of certain changes in a Cologne factory, where, in addition to separating the pasting from the mixing, the pasting tables were furnished with glass cabinets and exhausts, this being necessary because the pasters sometimes had to add dry oxide to the paste. Before the introduction of these protective measures there were 37 cases of lead poisoning among 153 pasters; afterwards there were 9 among 194, and the following year, only 8 among 209.

PASTING PLATES.

Pasters work at tables which may be covered with glass and furnished with projecting wooden rims, or of wood with a glass plate laid on it, or simply of wood with no glass. Of course, glass is by far the best because it can easily be cleaned at the end of the day's work, while wood becomes impregnated with the oxides and can not be scrubbed clean. It is desirable to have a raised rim around the edge of the table to keep the paste from dropping on the floor.

There is a great difference in the pastes used in the different plants, and the same plant may use several kinds. Sometimes the paste is

[1] Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, 1902, vol. 34, p. 550.

decidedly moist and takes some time to dry and become dusty; again, it may be so dry as to crumble. There are pasters who wear leather or rubber gloves and use wooden spatulas to rub the paste into the grid, but the majority wear no gloves and many knead the paste with their fingers. It is doubtful whether gloves afford much protection, for so many men have a habit of taking them off and then putting them on again over dirty hands.

In three large plants the pasting tables are furnished with an exhaust system, though in one of the three this is installed only at the tables for red lead paste, not for the litharge. The arrangement consists in an opening, wide or narrow, along the far edge of the table opposite the paster or along the right-hand edge, with a board projecting over it and an exhaust behind it. Such an exhaust is of very doubtful value, as the wet paste on the table is not in itself a source of danger. In no case was it possible to see any dust arising from the paste which was under manipulation. The danger comes from the paste that has fallen and dried on the edges of the table, on the floor, and on the men's clothes, and the exhaust can not catch up dust from these places. Pasting rooms are always scarlet and yellow from red lead and litharge dust, though they are supposed to be cleaned every night. The part of the room devoted to litharge paste never looks as dusty as the part devoted to red lead, because the latter is such a vivid color, while litharge is about the color of wood and does not show on tables and floors. One superintendent, however, said that he had more trouble with lead poisoning from the litharge paste than from the red lead; he thought it was dustier when it dried than red lead.

Rogers and Vogt[1] found in one pasting room, just over the table, 4.2 milligrams of lead in a cubic meter of air, and in a second 1.2 milligrams. These quantities indicate that in the first factory it might be possible for a man to breathe in, during the day's work, 18.9 milligrams, and in the second 5.4 milligrams.

The dust in the pasting room is increased where the men are allowed to throw on the floor strips of paper covered with paste; these soon dry, and as the men walk back and forth over them the dry paste is ground into dust. This is seen in factories where the process of drying the plates is hastened by pressing strips of paper on them much as one would use a blotting paper. These papers must be pulled off and then, covered with oxides as they are, they are sometimes thrown on the floor to be gathered up at the end of the day. In two plants, however, they are dropped into receptacles so that they do not spread the dust as they dry.

One kind of plate is known as the "ironclad." This is a light grid made of slender parallel rods of metal over each of which is

[1] Second Report of the New York State Factory Investigating Commission, vol. 2, pp. 1129 and 1131.

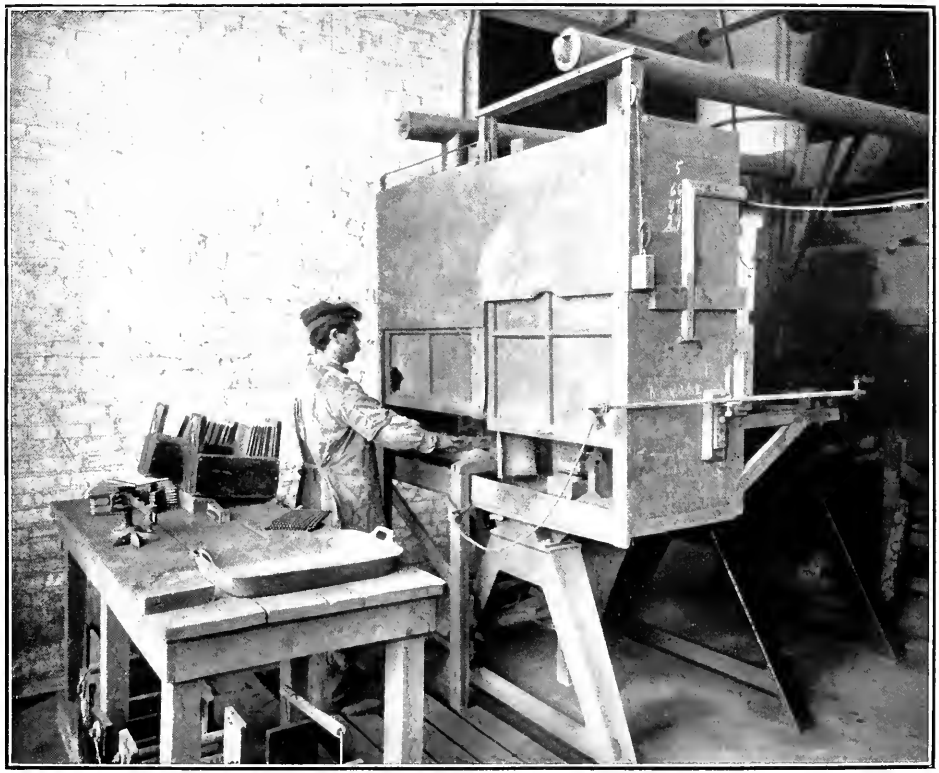

PLATE 6.—FILLING IRONCLADS.

slipped a very loosely fitting rubber tube with narrow openings in its circumference. The grid is placed upright on a table under a glass case and dry red lead is forced into the spaces between the rubber tubes and the rods, the grid being violently shaken all the time to shake the red lead down. It is an extremely dusty process and in spite of the protection of the glass case, there were heaps of dust all around the place in the one plant in which these plates are made (see pl. 6). One man working at the machine for filling these grids had his face powdered with red lead and the red color could be seen in his nostrils. The full grid is taken to another table which also is provided with a glass case, is placed in a frame, and the end is fitted on, and the connectors burned. This second table was of wood, with wide cracks, and there were quantities of dust over it and over the floor. From this table the plates go to the acid tank.

DRYING PASTED PLATES.

The pasted plates, if they are small, may go at once to the tanks in the "forming" or "pickling" room, but large ones are usually dried first because the acid in the pickling trough penetrates more quickly if the paste is dry. This drying is done either in a separate room or on racks in the pasting room. When the plates are dry their surface has set like cement and is hard and firm, yet they can not be handled without raising dust, the shelves on which they rest are always covered with dust, and the men who take them off the racks and carry them to the assembling room have a very dusty piece of work. When, as is often the case, the drying cabinets are in the paste room, this makes another source of air contamination in that room.

FORMING OR PICKLING.

The forming room is large and usually well ventilated, filled with long troughs of dilute sulphuric acid in which are immersed large numbers of plates, connected by a copper bar. A current of electricity is sent through the plates, and when they are taken out they have been "formed" and the positive one is covered with a coating of the brown peroxide, the negative with gray, spongy lead. In the forming room and, to a slighter extent, in the charging room where a second treatment with an electric current takes place, the fumes of sulphuric acid are strong enough to cause much discomfort to a person not accustomed to them. Nevertheless the men working there do not seem to experience any irritating effect upon the eyes and throat, and German factory inspectors say that physicians find no increase in lung trouble or in inflammation of the eyes among these men. Chyzer,[1] however, after an examination of some Aus-

[1] Annales d'hygiène publique et de médecine légale, 1908, 4th series, Vol. X, pp. 239–260.

trian factories gained quite a different impression, and in order to decide the question he subjected rabbits to an atmosphere similar to that in forming rooms. He found that there was enough sulphuric acid in such air to cause bronchitis and even foci of inflammation in the lung tissue of animals. The bubbles which are always rising from the acid troughs carry with them tiny drops of acid, and Chyzer found, in a forming room with open windows, a deposit of 1.28 grams of sulphuric acid on one square meter of surface. In a room with closed windows the quantity on a surface of this extent was 3.97 grams. The workmen, he found, often suffered from bronchitis and nosebleed and the acid fumes also exerted an injurious effect on the enamel of the teeth. On the other hand, Böttrich, one of the physicians to the Hagen factory, believes that these acid fumes are actually beneficial. None of the physicians interviewed in the course of the present study had noticed any ailment among the men traceable to their occupation in the forming room.

When the formed plates are taken from the acid, they are washed and soaked in various solutions, the composition of which is always a trade secret, but the work is of no apparent importance from the writer's point of view.

ASSEMBLING AND LEAD BURNING.

The dusty processes begin again in the assembling room where the formed plates are grouped and fastened together by lead strips. A group of positive plates is then fitted together with a group of negatives and between each pair of plates is slipped a thin strip of wood. This work is known as assembling and the men as assemblers. Lead burning consists in fastening the groups together and connecting positive and negative groups by a soldering process in which pure lead is used instead of ordinary solder, and the heat is applied by means of an oxyhydrogen flame. This is done in the same room as the assembling and the two are often spoken of together as assembling, or the work of the whole department may be designated as lead burning. This makes it difficult to find out exactly what kind of work was done by a man employed in such a room. Other occupations are frequently carried on in the assembling rooms, such as the inspection of formed plates before they go to the assemblers, the imperfect ones being rejected, or straightened, trimmed, and filed. Small plates which have been pasted in pairs are sawn apart in this room and both the trimming and sawing are productive of a great deal of dust because the plates are now covered with dry oxides. The cleaning of the edges and the lugs of pasted plates is another dusty piece of work usually carried on here. The projecting part of the plate, known as the lug, and the edges of the plate have,

PLATE 7.—CLEANING LUGS AND EDGES OF PASTED PLATES.

This machine has a guard which serves to prevent accidents to the man's fingers and is also connected with an exhaust fan to remove the dust.

PLATE 8.—CLEANING LUGS AND EDGES OF PASTE PLATES WITHOUT ANY EXHAUST.

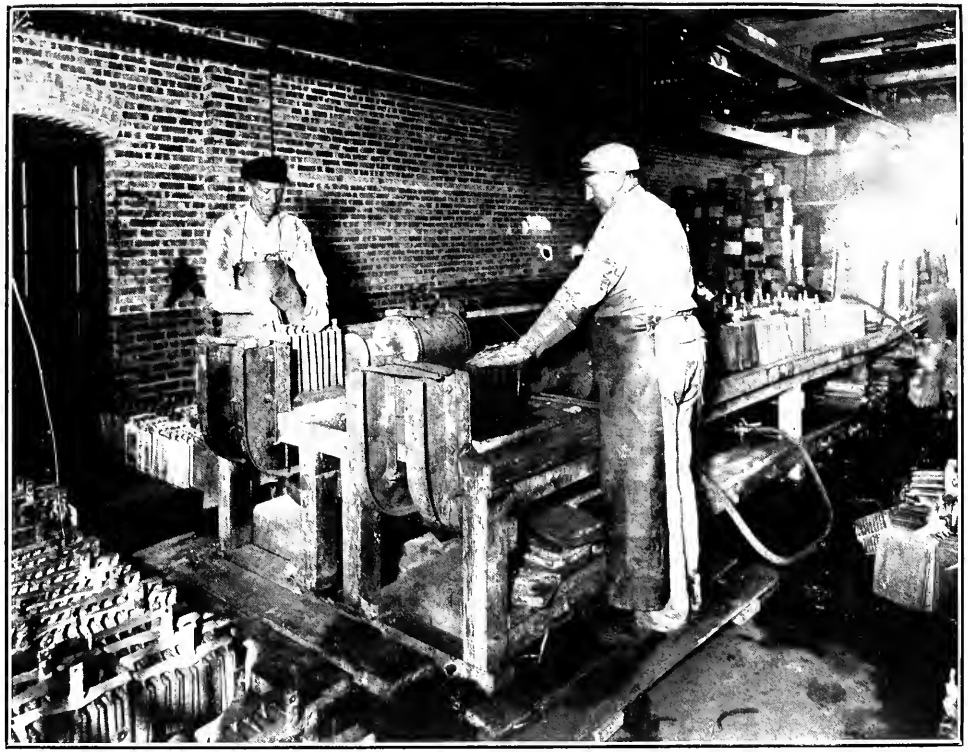

PLATE 9.—ASSEMBLING AND CLEANING.

The man to the right is placing strips of wood between the plates; the one to the left is scraping and polishing the lugs.

PLATE 10.—LEAD BURNING.

The workman holds a piece of pure lead in his left hand and an oxyhydrogen burner in his right hand. He is protected from the fumes by a respirator, an unusual precaution in this sort of work.

in the process of pasting, become more or less smeared with paste and in order that good connections may be made this dried oxide must be cleaned off and the metal brushed and scraped till it is bright. The work may be done by hand or by machine.

The accompanying illustrations (pls. 7, 8, and 9) show the operations of cleaning and assembling. The machine shown in plate 7 is carefully equipped to reduce the danger to the worker as much as possible. In spite of the exhaust, however, an accumulation of dust and bits of paste is seen beneath the machine. Plate 8 shows the method of cleaning plates by hand, in which the worker has either no protection at all or only such as is given by a respirator. Plate 9 shows conditions when, as is often the case, cleaning and assembling are carried on in the same room.

The assemblers proper handle dry oxide plates, but not in such a way as to cause the production of much dust. The lead burners have work which German and English authorities consider particularly dangerous. They use a small but very hot oxyhydrogen flame to melt a narrow bar of pure lead (see pl. 10). The question is how much volatilization of lead is caused by the tiny flame. As we shall see later, the most recent British reports show more lead poisoning among the lead burners than among any other workmen in the electric accumulator factories, and British factory inspectors are advising the installation of air exhausts at the work benches to protect these men. The German factory inspectors also report a rate of lead poisoning among burners in certain factories even higher than that among pasters, and they have shown by means of pieces of moist filter paper suspended above the lead burner that lead passes into the air.[1]

Roth, however, questions the interpretation of these tests. He repeated them and found that when the workman was engaged only in lead burning there was no appreciable lead caught on the filter paper, but when, after burning, the man proceeded to polish the surface of the lead with a steel brush, there was a distinct deposit of lead dust on the paper.[2]

In the United States the lead-burning department has a much better reputation among physicians and workmen than has the mixing or pasting department, and very few cases of lead poisoning could be traced to it in the plants visited. It may be that we have so much more sickness in our pasting and mixing rooms that the less dangerous departments are overshadowed. Another explanation was offered by an expert familiar with the industry in England as well as in this country. He said that the English use in lead

[1] Jahresbericht des Regierungs- und Gewerberates für die Regierungsbezirk Arnsberg pro 1896.
[2] Beiträge zur pathologischn Anatomie und allgemeinen Pathologie VII Supplement 1905, S. 184–197.

burning a pure oxyhydrogen flame, while the Americans use hydrogen mixed with atmospheric air in which the oxygen is greatly diluted. The pure oxygen makes a much hotter flame and therefore causes more volatilization of lead. The source of lead dust noted by Roth, the polishing of the hardened lead with a steel brush, was not seen in any lead-burning room visited in the course of this inquiry. Rogers and Vogt were able to demonstrate in one factory 2.6 milligrams of lead per cubic meter in the air over a lead burner's bench, and 1.8 grams in another,[1] but in view of the many dust-producing processes which are carried on in those assembling rooms, it is impossible to estimate how much of the lead represented volatilized oxides and how much dust.

FINISHING.

This term is a little confusing, for it is used both for the trimming and polishing of grids in the casting room and for the final making up of batteries. In this report it is used in the latter sense only. The plates which have been assembled and burned together, go next to the charging room for the passage of the second electric current. The accompanying illustration (pl. 11) shows the method of charging. The room in which this operation is carried on is like the forming room except that the acid fumes are less strong. The plates are then brought to the finishers who place them in cells filled with acid and fasten on the covers and the outer connectors, thus making up the batteries. The only lead work here is making the connectors on the outside of the battery. This is essentially the same as lead burning, for it is done with pure lead and the oxyhydrogen flame.

Small plates are placed in hard-rubber containers, medium-sized ones in glass and large ones in wooden boxes lined with sheet lead. The making of these lead-lined containers is similar to lead burning, the edges of the lead sheets being welded together by the oxyhydrogen flame. It may be done in the assembling room or in the room for casting Planté plates. One foreman called attention to the fact that in making the largest of these containers, the burner was obliged to put his head inside it or he would not be able to make accurate joinings, and of course the slightest leak would spoil the battery. If there really are fumes produced in such lead burning, the workman can not avoid inhaling them.

HYGIENIC CONDITIONS.

An inspection of the storage-battery establishments in this country gives one the impression that only lately have the employers awakened to the dangerous character of the work they have been

[1] Second Report of the New York State Factory Investigating Commission, 1913, vol. 2, pp. 1130, 1131.

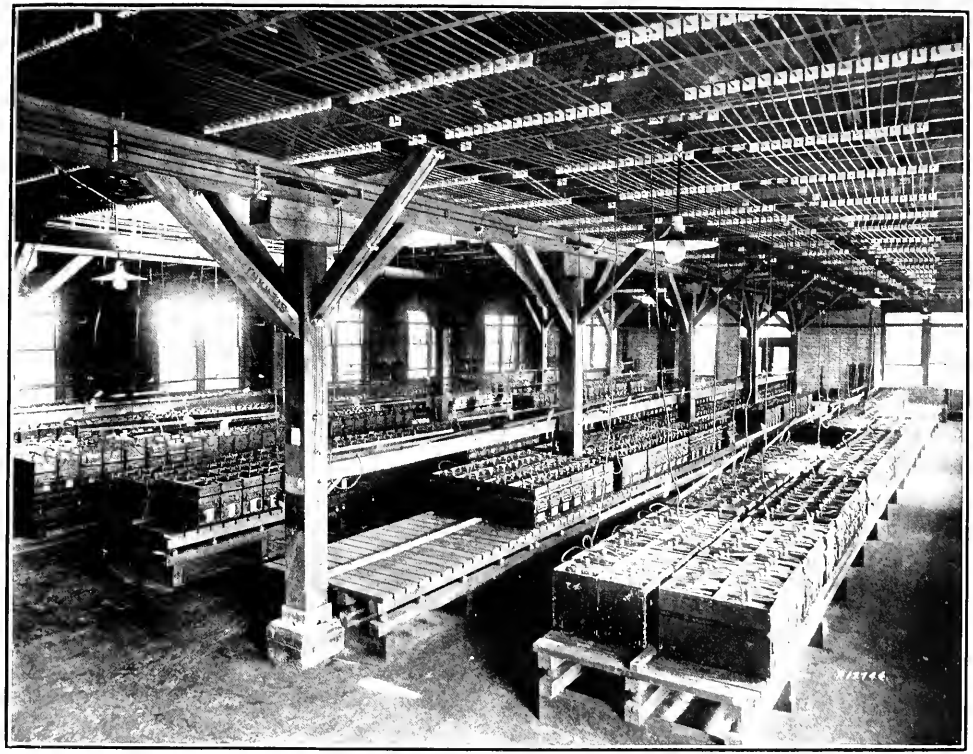

PLATE 11.—CHARGING ROOM.

An unusually light and well-ventilated charging room. The jars are all filled with dilute sulphuric acid, and the air is necessarily very irritating, even with the windows open.

carrying on, and that they are not yet well enough instructed in its dangers to recognize all the places that should be safeguarded, nor to appreciate the importance of personal care of their employees.

Of the five largest plants that were visited, all but one are new and well built. Cement floors were found in three. The advantage, of course, of a cement floor is that it can be thoroughly cleaned, whereas in the case of a wooden floor the powder is ground into the wood and into the cracks between the boards and it is impossible to get all of it out. One of the three in which there is a cement floor is cleaned by flushing at the end of the day. The second has a very elaborate vacuum-cleaning system, and the third is cleaned simply by sweeping with wet sawdust, because the cement in this factory is not waterproof. All three of the plants are fairly clean for the most part, but one of them has a great deal of dust in the pasting room. Of the two larger plants with wooden floors, one is new, and the floors are still smooth and reasonably clean; the other is old, the floors are worn, the dust is ground into them, and they could not possibly be made dust free. In this last plant an attempt has been made to improve conditions in the pasting room by covering the floor thickly with damp sawdust, but the effect is rather spoiled by the piles of oxide-covered papers thrown on the floor after being taken from the pasted grids. This last plant is the only one in which there is overcrowding. The rooms are too small. In all the others, there is ample space, light and ventilation; indeed the construction of these four plants is better than their upkeep, which in no instance is so careful as to secure scrupulous cleanliness.

It is quite surprising to an outsider to see how a manager will point with pride to a new and expensive device for carrying off dust through exhausts and will quite fail to see the dust on the floor where he is standing, dust which needs no newer or more expensive equipment for its safe removal than a broom and a pail of wet sawdust.

The smaller factories differ from the larger chiefly in having the different processes less well separated. For instance, in one, mixing oxides, paste making, pasting, forming, and lead burning are all carried on in the same room, leaving only the casting and trimming to be done in a small room off the main one. Repair shops have another bad feature in the dust from old rejected battery plates. These are usually thrown in a heap in a corner until enough accumulate to be sold to a refinery. The branch establishments, which only assemble batteries, are much safer than the factories proper, since everything that has to do with pasting is eliminated. Assembling and lead burning and the final finishing are the dangerous processes here, but it is very much easier to manage the dust problem in such a place. However, in these plants there is also a certain amount of work with old batteries that adds an element of dust.

SANITARY EQUIPMENT.

The making of paste and the pasting of plates is recognized in all the larger plants and in most of the smaller ones as dangerous work, and though the employer may not explain this fact to his workmen he almost always provides some kind of washing facilities for men engaged in this work. The work of casting and trimming and lead burning and assembling is regarded more lightly by the employer, and sometimes the men employed in such work are not provided with any place where they can wash.

Two of the five largest plants have paid very little attention to the personal care of their men. The pasters in one of them were wearing old trousers and aprons which did not cover their shirts so that when they go home at night they must carry red lead and litharge dust in their shirts. The only provision for washing is a sink with cold water; if the men want hot water they must fill the sink and run steam from a hose into the water to heat it. If they wish soap and towels, they must pay for them. In the other plant there are sinks with only cold water in the pasting room, but it is said that the men can get pails of hot water from the floor below. No towels, soap, nailbrushes, or overalls are provided, and there is no lunch room. The mixers and pasters, however, are given leather gloves. In a third factory conditions are better. There is an excellent washroom next to the pasting room, very well equipped and with ventilated lockers for the men's clothes, but it is for the use of the pasters and mixers only. There is no lunch room at all. A fourth factory has a washroom close to the pasting room with a long sink, hot water, soap, towels, and nailbrushes. Full suits of overalls are furnished by the company to the pasters and mixers. When noon came, during the visit made to this plant, the men from the pasting and mixing department all went to the wash room at once; but they did not take off their dusty overalls before eating lunch, and no lunch room is provided for them. Only one of the five plants makes really abundant and satisfactory provision for the personal care of the men, and, fortunately, this is the largest plant in the country. Here there are modern, well-equipped, and very well maintained wash rooms, a room with shower baths and a large pleasant dining room and recreation room. The men may buy a hot dinner in the lunch room and the company regulates the price which the restaurant keeper may charge. Gas, steam heat, and the use of the room are furnished by the company.

So far as could be ascertained, even in places where the men are well cared for, they do not seem to be instructed in the dangers of the work, perhaps from fear of frightening them away. Of 21 men who were asked whether they had ever been told that the stuff they were using was poisonous, only 2 replied in the affirmative.

MEDICAL CARE.

The Ohio law requires that men in this employment be examined once a month by a physician employed by the company. Neither the New York nor the Pennsylvania laws contain this provision for employers of storage-battery works, but there are physicians attached to the two large New York plants and to one of the two in Pennsylvania. In the two former the physician takes care only of the men who apply to him for advice, but in the Pennsylvania plant the physician makes almost daily visits and regularly examines the men employed in the more dangerous kinds of work and also the applicants for work in these departments. He suspends from work, or transfers to other departments, men whose teeth are in bad condition, or who are physically below par, and they are not allowed to return until he has pronounced them to be in fit condition. Men found to be alcoholic are discharged. This physician lays special stress upon the condition of the teeth as a contributory factor in lead poisoning.

WAGES, DURATION OF EMPLOYMENT, ETC.

The men employed in storage-battery works are a shifting class, especially the pasters, though they are usually paid fairly good wages, sometimes decidedly above the rate ordinarily paid for unskilled labor. According to the employers men in this trade in Ohio receive from $1.90 to $3.50 a day. In New York a skilled worker at a machine in the casting room stated that he had earned $21.90 a week. Pasters are paid less. Three pasters in New York gave their weekly wages as $12, $12 to $13.50, and $13.75, respectively. A fourth paster received $15. Pasting is, usually, piecework. Two men employed in the forming room received each $11 a week. The books of one large concern in Philadelphia showed that pasters were paid from $14 to $18 a week. The wages of lead burners were higher, reaching $19.50 a week. Two mixers (the mixing in this factory is done by hand) and one man who acted as helper to a lead burner said that they were paid only $9 a week.

In spite of reasonably good wages, men do not seem to remain long at the work, for among 70 who were interviewed only 17 had worked as long as a year and 41 had worked for less than six months.

The following statement shows the period of exposure of 70 cases of lead poisoning in this industry:

Less than 1 month	3
1 month and less than 2 months	6
2 and less than 3 months	8
3 and less than 4 months	11
4 and less than 5 months	6
5 and less than 6 months	7
Total, less than 6 months	41

6 and less than 7 months	4
7 and less than 8 months	1
8 and less than 9 months	3
9 and less than 10 months	0
10 and less than 11 months	2
11 and less than 12 months	2
Total, less than 1 year	53
1 year and less than 2 years	8
2 and less than 3 years	0
3 and less than 4 years	2
4 and less than 5 years	3
5 and less than 6 years	0
6 and less than 7 years	2
12 years	1
13 years	1
Total, over 1 year	17

The majority of the workmen are unskilled foreigners, and the division of work between them and the English-speaking workers depends largely upon the degree of skill required. Lead burning is skilled work, and, like molding, is often done by English-speaking men. The mixing of the oxides and of the paste is under the control of a skilled man, and the making of Planté plates is mostly skilled work. On the other hand, the pasting, assembling, trimming, and transporting are done by unskilled foreigners. In other words, some of the dustiest and most dangerous of the processes are given over to unskilled men, who often do not understand English. A good many of them look very young, and in some factories boys of 16 are employed, especially in hand trimming and in assembling.

LEAD POISONING IN THE INDUSTRY.

In casting and molding, provided the room is separate from the one in which paste plates are handled, the only danger is from fumes and possible particles of metallic lead. In trimming, polishing, and filing the molded grid only metallic dust is encountered, and this is far less dangerous than lead fume or oxide dust,[1] so that if these processes were carried on in a separate room the work would be comparatively safe.

Mixing the oxides, making the paste, and applying the paste expose the men to the action of red lead and litharge, and the danger is in proportion to the amount of dust produced. Oxide mixing can be

[1] The oxides of lead are about as soluble in human gastric juice as white lead (basic carbonate), but the lower oxides are lighter and more fluffy and dusty to handle, so that some authorities, such as Etz (Leymann's Bekämpfung der Bleigefahr in der Industrie, pp. 6, 7), believe that litharge causes more harm than white lead. In a study made for the Bureau of Labor (Bulletin 95, White Lead Industry in the United States, p. 259) it was found that in factories where both white lead and the oxides were manufactured the men engaged in the oxide department had a higher rate of lead poisoning than those in the white lead.

made safe by properly inclosing the dump for the dry powder and the machines; the same is true of paste making. Rubbing the paste into the grids is always a dangerous piece of work, but if the paste is very moist and the paste rooms kept clean, the dangers from the work are minimized. In such cases the important thing is to see that the workman washes at the end of his work and leaves his working clothes behind him; in other words, to see that he does not get the dust into his mouth with his food or tobacco, nor carry it home in his clothes. But if the paste be rather dry and crumbly and the tables and floors be allowed to become dusty, no care in the matter of personal cleanliness will really save the men from lead poisoning, because they will breathe in the dust. Legge and Goadby [1] advise keeping floor and workbenches in the paste room always damp.

After the plates have been filled with paste and dried, the further processes of taking them out of the drying cabinets and carrying them to the assembling room, assembling, lead burning, placing in receptacles, and finishing, all involve exposure to a certain amount of oxide dust from these plates, as well as exposure to fume from the use of the oxyhydrogen flame on pure lead.

The report of the New York State Factory Investigating Commission states that out of 67 cases of lead poisoning reported among indoor workers in that State during one year, 15 were storage-battery workers.[2] In the course of investigations in storage-battery factories, Dr. Graham Rogers found men at work who showed typical signs of lead absorption. In one factory three cases had already been reported to the New York Department of Labor and in addition to them Dr. Rogers found three boys under 18 who showed typical anemia; 4 pasters with marked pallor, 2 with marked anemia and the lead line, and a seventh who was under treatment for lead poisoning. Two assemblers were found with symptoms of lead poisoning and a lead burner with anemia and a lead line. The mixer showed evidence of plumbism. The regular force in this factory engaged in the lead processes was 110 to 115 men.

In the second factory 13 cases had been reported, mostly pasters. During Dr. Rogers' visit 4 cases were discovered in the pasting room and the greater part of the force in that room impressed the investigators as showing signs of lead absorption.[3]

In this same report is given the result of a detailed investigation of 31 cases of industrial lead poisoning traced to Niagara Falls plants, all but one of which came from three storage-battery factories.[4] The investigation was made in the summer of 1912 and the

[1] Lead Poisoning and Lead Absorption, London, 1912, p. 282.
[2] Second Report of the New York State Factory Investigating Commission, 1913, vol. 2, pp. 1128–1130.
[3] Ibid., p. 1132.
[4] Ibid., pp. 583–601.

largest number of cases fall in the year 1911. In that year there were 17 cases; in 1912, 9; in 1910, 3, and in 1909, 2. There are several interesting details in this report. Two of the men contracted lead poisoning while inspecting and cleaning plates; in 5 out of the 30 cases the men seem to have been employed with metallic lead only, and one was in the charging room, where in a well-managed factory there should be no danger from lead. As would be expected, the cases found by the investigators were of a fairly serious or very serious type. Mild cases do not make much impression and are soon forgotten.

In the present investigation cases of lead poisoning were found which had occurred during the year 1913 in all of the following processes:

Casting, including Planté plates.
Trimming and filing.
Mixing oxides.
Making paste.
Pasting plates.
Cleaning pasted plates.
Taking papers off pasted plates.
Carrying pasted plates to forming room.
Polishing lugs.
Assembling.
Lead burning.
Filling ironclad plates with dry oxides.

SOURCES OF INFORMATION CONCERNING THE POISONING.

The three States in which the greatest amount of storage-battery manufacturing is done are Ohio, New York, and Pennsylvania. The first two require by law that all cases of industrial lead poisoning shall be reported to a central office. A similar law in Pennsylvania has just come into force. The reports from the Ohio Department of Health proved to be very nearly complete, for a careful search revealed only a very few cases in addition to those already reported. In New York, on the other hand, the reports are far from complete, and it was necessary to question the men themselves and interview the physicians in order to discover even approximately how much lead poisoning there was during 1913 in this industry. Some of the physicians are careless about sending in reports, although they are able to verify a case when the record is brought to them, and others say frankly that they do not trouble to send in reports of any but the severe cases. The physicians attached to the factory, who naturally see the majority of cases, are not always willing to make public the actual number of men who have had lead poisoning in the plant. In Philadelphia it was necessary to depend entirely upon hospital records and interviews with physicians because the law

requiring the reporting of lead poisoning has been in effect so short a time. Many of the cases in the lists are known to the writer only by the name of the man and the name of the physician who made the diagnosis. The men had quit work and could not be traced, and it was impossible to learn in what process they were employed or how long they worked before they began to feel the effects of the lead. Among those who could be approached a very large majority were employed as pasters, but it would probably be wrong to conclude from this that pasting is as much more dangerous than other kinds of work as this would indicate. As a matter of fact, the pasters are all, or almost all, foreigners, and much more likely to go to dispensaries and hospitals for treatment than are the American-born or at least English-speaking lead burners and molders.

NUMBER OF CASES IN FIVE LARGE FACTORIES.

In what follows the facts are given as it was possible to ascertain them, although it is realized that the information is far from complete. Only the five largest plants are considered here. The force employed in these five plants in processes which involve the use of lead or lead salts numbers about 915, and of these about 303 are exposed to metallic lead dust and the fumes from melted lead, 274 to lead oxides, and 338 to both. They are divided approximately as follows:

Casting, sawing, trimming, etc	303
Mixing	16
Pasting	246
Lead burning, assembling, polishing lugs, etc	338
Filling ironclads	12
Total	915

The cases of lead poisoning which were found to have occurred during 1913 in these five plants are as follows:

NUMBER OF CASES OF LEAD POISONING IN FIVE LARGE PLANTS DURING 1913.

Number employed in lead work in five plants.	Cases from hospitals and dispensaries.	Cases from doctors' records.	Total cases.	Rate per 100 employees.
915	43	121	164	17.9

This means that, with incomplete records, these five factories had at least one case of lead poisoning for every five to six men employed, or 17.9 per 100 employed. When one considers how scanty was the information obtained in regard to three of the five plants and how hard it is to follow up a shifting force of migratory foreigners

it is easy to see that these figures must necessarily fall far below the truth.

If these cases are divided according to occupation, which can be done only in the case of 70, the greater danger of work with the oxides becomes apparent.

CASES OF LEAD POISONING CLASSIFIED AS TO CHARACTER OF EXPOSURE.

Character of exposure.	Employees exposed.	Cases of lead poisoning.	Rate per 100 employees.
Exposed to metallic dust and fumes	303	3	1.0
Exposed to oxides	274	39	14.2
Exposed to both metallic dust and fumes and oxides	338	28	8.3

The same thing is shown in some unusually full records from two plants which give occupation as well as other information in regard to the cases of lead poisoning. In these two the cases were described as follows:

CASES OF LEAD POISONING IN TWO PLANTS CLASSIFIED AS TO OCCUPATION OF EMPLOYEES.

Occupation.	Employees exposed.	Cases of lead poisoning.	Rate per 100 employees.
Casting, including Planté	177	[1] 3	1.7
Mixing, including filling of ironclads	20	8	40.0
Pasting	160	31	19.4
Assembling and lead burning	262	28	10.7

[1] This does not cover all the cases during 1913 in these two plants, for in one of them records were available for six months only.

In another plant the physician showed a list of men who had been laid off during three months' time because they showed signs of lead absorption. Most of these men were simply suspended temporarily.

CASES OF LEAD POISONING IN ONE PLANT CLASSIFIED AS TO OCCUPATION OF EMPLOYEES.

Occupation.	Employees exposed.	Cases of lead poisoning.	Rate per 100 employees.
Casting	117	3	2.6
Mixing, including filling of ironclads, etc	18	6	33.3
Pasting	100	18	18.0
Assembling and lead burning	213	31	14.6

From all these records it is plain that mixing, which involves handling the dry oxides, is the most dangerous work. The filling of "ironclads" has been included under this heading because in that work, also, the dry oxides are handled. Next in danger to mixing comes pasting, then assembling and burning, because in both of

these there is oxide dust, and, finally, much less dangerous than any of the others, casting and trimming, where there is only metallic lead or possibly some fumes. However, it may be true that there is more lead poisoning among lead burners in these factories than was found. One physician said that he had made a careful survey of 100 men who were employed in departments other than pasting or mixing. They were casters, lead burners, and storeroom men, and in 20 of the hundred he found signs of lead absorption.

TYPE OF LEAD POISONING.

Legge and Goadby [1] state that during the 10 years from 1900 to 1909, inclusive, there were 285 cases of lead poisoning in this industry reported in Great Britain, but that a comparison of the proportion of severe cases with the proportion among the cases in all lead industries shows that the making of electric accumulators has less than its share of severe forms of plumbism.

The cases are usually acute, with colic and in severe instances encephalopathy, but not paralysis. This is explained by the fact that men do not remain long in this kind of work and that they are exposed to the dust of salts of lead which is quickly absorbed and which causes acute plumbism.

This was also found to be true of the cases of lead poisoning in the making of accumulators in the United States concerning which the writer has been able to gather detailed information. Among 64 cases, 8, or 12½ per cent, would be classed as severe, 25, or 39 per cent, as moderate, and 31, or 48.4 per cent, as mild. This is a larger proportion of moderate cases than that in the British reports. There the figures are: Severe, 20.6 per cent; moderate, 24.9 per cent; and mild, 53.7 per cent.[2] The explanation of this difference is probably that mild cases are hard to trace in this country, for they are quickly forgotten. Still this does not mean that there is always a quick recovery from these acute attacks and that the man may go back to work after a few days' illness. His incapacitation for work may even be longer than the employment which led up to his illness. For instance, the pasters in a storage-battery factory usually suffer from rapidly developing and uncomplicated lead poisoning, yet if these men are followed up it will be seen that, simple and acute as the disease is, the effects are sometimes slow to disappear. This is the record of 12 such cases which were looked up within a year of the illness.

[1] Lead Poisoning and Lead Absorption, London, 1912, pp. 46, 51.
[2] Ibid., p. 48.

INCAPACITATION OF 12 LEAD-POISONED EMPLOYEES, CLASSIFIED AS TO TIME EMPLOYED.

Length of time employed.	Length of time incapacitated.
8 months	3 weeks.
3 months	3 weeks.
6 months	4 weeks.
5 months	5 weeks.
2½ months	5 weeks.
3 months	2 months.
5 months	2 months.
5 months	3 months.
2½ months	3 months.
6 weeks	3 months.
6 months	4 months.
6 months	4 months.

The symptoms of poisoning in most of the cases investigated came on rapidly. Records were obtained of 6 men who sickened after less than a month's exposure, and 3 more who had been exposed only a little over a month. One man who mixed paste by hand began to feel ill, with loss of appetite, headache, and digestive disturbance, after two week's work. He was a tall and strongly built man and said that he had never been sick in his life before, but he was obliged to go to the hospital at the end of 11 weeks. A paster in the same room who had had many attacks of lead poisoning and who had just been laid off by the doctor for 6 weeks, said that the men in his room always began to feel ill at the end of a month, but they could usually keep on working for a while longer and many of them came back again, even after a severe attack, because of the good wages paid.

The following table gives the length of time which elapsed between the beginning of the work and the first symptoms of lead poisoning in 60 cases. It shows that five-sixths of them were sickened after less than six months' work.

Period of exposure to lead before onset of symptoms in 60 cases.

Less than 1 month	6
1 month and less than 2 months	11
2 and less than 3 months	14
3 and less than 4 months	12
4 and less than 5 months	5
5 and less than 6 months	2
Total less than 6 months	50
6 and less than 7 months	2
7 and less than 8 months	2
8 and less than 9 months	0
9 and less than 10 months	2
10 and less than 11 months	0
11 and less than 12 months	2
Total, less than 1 year	58
1 to 2 years	1
4 to 5 years	1
Total, over 1 year	2

The symptoms of 40 cases of lead poisoning were reported in some detail, and when analyzed reveal the following facts: Twenty-four were cases of typical lead colic; 9 of the other 16 complained of abdominal pain, 7 did not. In 22 anemia was a marked feature. In 27 there was constipation and in 3 diarrhea. Vomiting was pronounced in 7, persistent nausea in 4, severe headache in 9, in 4 of which there was dizziness also. Myalgia was one of the chief symptoms in 7 cases. Twenty-three out of the 40 had nervous symptoms. Five of these cases are noted as showing "marked nervousness," while 4 had "obstinate insomnia"; 4 had weakness of the wrists; 3 had wrist palsy; 1 had a period of unconsciousness at the beginning of his attack of colic; another was taken with violent delirium while in the hospital for colic, and still another had repeated attacks of an epileptiform character. In 4 the physicians noted "mental dullness."

Of these 40 men 15 had never been sick before except for the diseases of childhood; 23 had had no former attack of lead poisoning, 5 had a history of an earlier attack, 4 had had two previous attacks, 1 had had four, and 7 said that they had been sick many times.

The only fatal case reported during 1913 was that of a Polish workman who had been employed for about two months, at what particular process is not known. According to the statement of the two physicians who saw him, he was taken with acute lead colic and his friends advised him to drink whisky to stop the pain, which he did to such an extent that he developed acute alcoholism also, followed by delirium tremens and death. The death certificate gives lead poisoning, with acute alcoholism as contributory cause.

LEAD POISONING IN THE INDUSTRY IN GREAT BRITAIN AND GERMANY.

If we compare the records of cases of lead poisoning during 1913 in the five large factories in the United States with the most recent British and German records, we can see the difference made by careful sanitary and medical control of this industry.

The rate of poisoning in these five factories, as shown by records which are far from complete, is almost 18 for 100 men employed. According to Wagener[1] the rate 20 years ago in five German factories was 14 per 100, which even at that time was considered frightfully high (*erschreckend hoch*).

The attention of the factory inspectors was called to lead poisoning in the accumulator works in Berlin as early as 1889, and as a result certain improvements were introduced which were gradually extended to other regions, and by 1898 the detailed regulations which are now in force were made applicable throughout Germany. Their effect is strikingly shown in the records of several of the large factor-

[1] Deutsche Vierteljahresschrift für öffentliche Gesundheitspflege, 1902, vol. 34, p. 533.

ies. For instance, the German Factory Inspection Report for 1912 [1] contains the history of lead poisoning in a single large factory in the Arnsberg district as follows:

CASES OF LEAD POISONING AMONG EMPLOYEES IN ONE FACTORY IN GERMANY, BY YEARS, 1897 TO 1912.

Year.	Number employed in lead processes.	Cases of lead poisoning.		Year.	Number employed in lead processes.	Cases of lead poisoning.	
		Number.	Rate per 100 employees.			Number.	Rate per 100 employees.
1897	189	40	21.16	1905	419	8	1.91
1898	237	18	7.59	1906	465	7	1.51
1899	316	9	2.85	1907	461	6	1.30
1900	298	6	2.01	1908	426	5	1.17
1901	237	3	1.27	1909	411	3	.73
1902	216	5	2.31	1910	379	4	1.05
1903	263	5	1.90	1911	408	5	1.23
1904	374	8	2.14	1912	411	4	.97

The effect of the regulations which came into force in May, 1898, is shown clearly in this table.

Here is a brief résumé of the regulations for the control of this industry in Germany: [2]

Adequate ventilation: floors impervious to water, not made of wood, or linoleum, or soft cement in any room in which lead is handled. Walls smooth, covered with washable paint or whitewashed once a year.

Casting, polishing, and pasting each in a separate room.

Hoods over melting pot and over lead burning. No lead dust to be allowed to escape in the course of cutting and polishing.

Hoods with exhaust over paste mixing and pasting.

Floors to be cleaned with water twice a day.

Separate lunch rooms, separate dressing and wash rooms, washing to be compulsory, one bath a week. Work clothes to be provided consisting of a full suit and cap. Soap, towels, and brushes to be provided.

No women or minors to be employed.

Pasters and mixers to be allowed to work only eight hours a day with an hour and a half for lunch, or six continuous hours. Medical inspection once a month.

Some factories go beyond even these requirements. Thus the Hagen factory [3] furnishes milk free of cost to the workmen. It is probably the model factory of this kind in the world and without going into detail the most important features may be noted. All the pig lead for the casting kettles is handled with gloves, and no case of

[1] Jahresberichte der Gewerbe aufsichtsbeamten und Bergebehörden für das Jahr 1912, vol. 1, p. 435.
[2] Wagener, Deutsche Vierteljahresschrift für öffentliche Gesundheitspflege, 1902, vol. 34, pp. 536–538.
[3] Jahresberichte der Gewerbe aufsichtsbeamten und Berghehörden für das Jahr 1912, vol. 1, p. 436. Also Inaugural Dissertation, Eric Pagels, Leipzig, 1910.

lead poisoning has occurred thus far among the men who transport pig lead or kegs of oxides or collect dross and refuse lead. Much of the casting is rendered less dangerous by the use of machinery, but there are still occasional cases of plumbism among the finishers and trimmers of castings.

In mixing, the oxides are dumped mechanically into a closed mixer provided with an exhaust, and here also the liquid constituents of the paste are added and the paste is mixed in this same machine. Only negative plates are pasted; the positive are Planté plates and the paste for the former is applied, not by hand but by machine.

In lead burning, the temperature caused by the flame is said not to be over 550° C. (1022° F.). The danger here is thought to be from dust and the workbenches in the assembling and lead-burning room are covered with fine wire netting which allows the dust to fall through and be caught in a space below.

All the floors are of smooth, impervious material—cement or zinc—and are thoroughly wet before they are swept. The only respirators in use consist of light, aluminum frames with thin layers of cotton slipped in and with a valve to let out the exhaled air. The men are given 15 minutes at noon and evening to wash and to change their clothes, and there are attendants in charge of the lavatories whose duty it is to see that the men rinse their mouths, brush their teeth, and subject their hands and nails to thorough scrubbing with soap. The physician in charge emphasizes the importance of care of the mouth and teeth and says that it has an influence in preventing the development of the lead line. The men who mix the paste and those who apply it take two baths a week, all others take one.

Medical examination of the men is made weekly instead of monthly, and ever since 1908 a chemist has been employed to examine the blood of all men who are suspected of lead poisoning. The blood is examined for the presence of basophilic granules in the red corpuscles, and if as many as 200 out of 1,000,000 red corpuscles are found to be thus affected, the man is suspended from any work with lead until his blood is normal again. Between 1908 and 1912, 85 suspected men have been examined and about half have shown this change in the blood. In some cases the number of degenerated corpuscles reached 24,000 per million.

The physician in this factory has described his method of examination as follows: Each week the men pass before him and he inspects the tongue and gums, tests the strength of the hands, and also examines them closely for traces of lead on the skin. When the man shows evidence of carelessness in washing, the doctor applies a solution of 0.4 per cent sodium sulphide, which by blackening the deposits of lead serves as a valuable object lesson to the man. He questions the man as to his health, makes a note of pallor, of fibrillary twitchings

of the muscles of face and forearms, and if he has the least suspicion that the man shows signs of lead absorption he orders a blood examination and on the outcome of that decides whether or not the man must be taken away from leadwork and put into some safe place, such as the carpenter shop. He makes it a rule that the men in the most dangerous parts of the factory must be changed to outdoor work for a week and then back again, since he finds that this change improves the blood count and lessens the number of granulated red blood corpuscles. This physician emphasizes the importance of giving verbal instructions to the men, which he says are worth far more than any number of written regulations.

All of these measures are amply justified by the excellent report as to lead poisoning for this factory. The record given on page 28 of the large factory in the Arnsberg district belongs to the Hagen works.

There is no statement in the German report as to lead poisoning throughout the whole industry in that country, but the British Annual Report of the Chief Inspector of Factories and Workshops for the year 1912 has a record of all the cases of lead poisoning in the making of electric accumulators in Great Britain. In 1911 the approximate number of men employed in processes which involve exposure to lead was 1,149 and the number of cases of lead poisoning reported was 24, with 1 fatality, which would mean an attack rate per 100 employed of 2.1. There was a notable increase, absolute and relative, in 1912; the number employed was 1,254, and there were 38 cases, with 1 fatality,[1] a rate of 3 per 100. The inspectors call attention to this increase and urge that exhaust ventilation be required to carry off the fumes from lead burning and the dust caused by filing and trimming.

There is an interesting detailed report of the examination of the men employed in one English factory.[2] The figures given do not represent cases classed as lead poisoning, but simply men who showed undoubted marks of lead absorption.

CASES OF LEAD ABSORPTION AMONG EMPLOYEES IN ONE FACTORY IN ENGLAND, BY OCCUPATIONS.

Occupation.	Number of employees examined.	Employees showing marks of lead absorption.	Rate per 100 employees.
Casting	28	4	14
Pasting	27	6	22
Forming	16	5	31
Lead burning	19	7	37
Filing, Finishing, Cleaning	29	9	31
Packing	16	3	19
Others	24	5	21
Total	159	39	24.5

[1] Great Britain. Annual Report of the Inspector of Factories, 1912, p. 205.
[2] Ibid., p. 201.

It is easy to see from this report why the dangers of lead burning and finishing were so apparent to the inspectors. The process of pasting and of mixing the paste, which with us is the most dangerous of all, has been well controlled in England and does not cause nearly as much trouble as the comparatively safer work of lead burning.

In 1910 visits were paid to two large accumulator factories in the city of London. As the vigilance of the factory inspectors has brought about various improvements during the last four years in British factories of this kind, it is probable that some of the features which were noted at the time of these visits as being open to criticism have since been corrected. On the whole even in 1910 conditions were superior in these factories to those in our own, chiefly because of better supervision of the men at work, greater personal care of the employees, and better housekeeping. We shall mention only the most important features in these factories. The casting rooms had in both instances hooded kettles provided with exhausts. In one the kettles were further protected by sliding panels of iron which could be open or closed according to the draft in the room. The surface of the lead in the kettles was covered with charcoal to prevent the formation of skim or dross. The Home Office assumes that lead fumes or oxide dust may escape from molten lead no matter how low the temperature, and therefore insists on hoods for the kettles.

In both factories the mixing rooms in which also the paste was made were quite separate; the floors were of cement, kept moist, and cleaned by flushing. The mixing was done under an exhaust draft in a closed machine, and the men at work wore respirators which in England consist of muslin bags tied over the mouth and nose. The scales on which the ingredients were weighed were also protected by a hood with an exhaust. In one factory 2 men were employed at mixing; in the other 14 took turns at it, 2 working at a time. Neither room was entirely dust free.

The paste was given out to the pasters, who worked in a room in which no other process was carried on. These rooms were large with cement floor, kept continually wet. The pasters stood on boards to keep their feet dry. The workbenches were covered with sheet lead and protected by a raised edge to keep the paste from falling to the floor. The men were furnished with full suits of overalls, oilcloth or leather aprons, and heavy leather gloves.

In both factories the drying room was open to criticism because of the fine dust on floors and shelves. It was said that they were flushed out once a week.

In the forming rooms they had a way of drawing off the acid entirely before the plates were taken out, which added to the comfort of the workmen removing the plates.

Assembling and lead burning were at that time carried on just as in American factories, with no special precautions against dust or fumes, because, as was explained by the factory inspector, these processes were not supposed to be attended with danger. As we have already noted, there has been a change of opinion since then and an effort is to be made to carry off the fumes and prevent the dust.

As is usual in British factories, the lavatories in these two conformed to the strict letter of the law, but were not luxurious. They were, however, entirely adequate. The men exposed to lead are required to take a bath once a week. There were large lunch rooms, and no food might be kept or eaten in any other room, nor were any of the men allowed to enter the lunch room before taking off their overalls and washing.

Medical inspection was monthly in one, every three weeks in the other. In the larger of the two factories, between 80 and 100 men came in contact with lead in casting, mixing, pasting, and drying. There had been no case of lead poisoning discovered among them during the preceding year. Here, as in the German factory, a man engaged in lead work who seemed indisposed was given a job in the open air temporarily. This company sold toothbrushes to the men at twopence halfpenny apiece, and if the man failed to use his toothbrush, if his teeth were persistently dirty, he was discharged.

The British special rules for the making of electric accumulators are published in full in the appendix; essentially they are the same as the German.[1]

The German rate of lead poisoning in this industry, or rather that of the greatest German factory, is less than 1 per 100 men employed, and the British rate is about 3 per 100 employed. The rate in our five largest factories is almost 18 per 100 employed, and this great difference must be explained by the neglect in this country of factory sanitation and of personal care of the men employed. No new legislation is needed to bring about reforms in this industry; the laws of Ohio, New York, and Pennsylvania are quite adequate. It is a question of adequate enforcement.

SUMMARY.

The ordinary storage battery, not the Edison, consists of plates of lead, or of lead grids covered with a lead oxide paste. In the preparation of these plates and grids the workmen are exposed to the

[1] The French law of October 1, 1913, covers establishments in which storage batteries are manufactured. The regulations, which are given in the appendix, are similar to the German and British, but there is one specially good section which requires that men who apply for employment in an accumulator factory must be examined by a physician and that they can not continue to work without obtaining a second certificate of good health at the end of the first month, and after that, at the end of every three months. The examining physician is paid by the company.

danger of lead poisoning through dust of metallic lead and through fumes from melted lead.

In making and applying the paste the workmen are exposed to still greater danger of poisoning from the oxides of lead.

The subsequent processes of assembling, lead burning, etc., involve exposure to the fumes of melted lead and to the dust from dried oxide paste.

These dangers can be obviated by installing hoods and exhausts to carry off fumes and dust, by substituting machine for hand work, by providing ample washing facilities for the workmen and insisting on strict cleanliness on their part, by providing a separate lunch room as the only place where food may be kept and eaten, and by keeping the premises where the work is carried on clean and free from dust.

Inasmuch as some risk always remains after all possible precautions have been taken, there should be thorough medical supervision of the men in order to detect and eliminate those who are oversusceptible to lead, to discover cases in the early stages, and to give instructions to the men on the care of themselves.

By using precautions such as these, German and British employers have greatly reduced the amount of lead poisoning in factories of this kind. In the largest German factory the rate of poisoning in 1912 was 0.97 per 100 employed, and in Great Britain the rate for all factories during this same year was 3 per 100.

In the United States the five largest factories were during 1913 employing about 915 men in work which exposed them to lead. It has been possible to discover 164 cases of lead poisoning which occurred among the employees of these plants in this one year. This makes a rate of 17.9 per 100 employed.

The largest proportion of lead poisoning occurred among the men handling lead oxides, the lowest among those handling metallic lead only. The disease was usually typical acute lead poisoning, with gastric symptoms predominating, but even an acute attack often resulted in incapacitation from work lasting for several weeks to two months or over. Out of 40 cases 23 had marked nervous symptoms. Chronic plumbism was rarely found, since the men hardly ever remain long at the work.

The employees in this industry in the United States are for the greater part of foreign birth; many speak no English and are ignorant of the dangers of the work, or if they recognize the danger, do not know how to protect themselves against it.

The difference between the American rate of lead poisoning and the British and German rates must be explained by the different standards of sanitation and management in this country as compared with those of European countries. None of the five large factories in the United

States comes up to the British or German establishments in cleanliness or in the removal of fumes and dust, and only one provides as careful medical supervision. Smaller factories in this country are even less well managed.

The three States in which the five largest factories are situated have already passed laws which cover this industry and provide safeguards for the men engaged in it, and if these laws are strictly enforced by intelligent factory inspectors there is no reason why our record of lead poisoning should not fall, as it has fallen under intelligent supervision in Great Britain and Germany.

APPENDIX A.—REGULATIONS IN GREAT BRITAIN FOR THE MANUFACTURE OF ELECTRIC ACCUMULATORS.[1]

Whereas the manufacture of electric accumulators has been certified in pursuance of section 79 of the Factory and Workshop Act, 1901, to be dangerous;

I hereby, in pursuance of the powers conferred on me by that act, make the following regulations, and direct that they shall apply to all factories and workshops or parts thereof in which electric accumulators are manufactured.

In these regulations "lead process" means pasting, casting, lead burning, or any work involving contact with dry compounds of lead.

Any approval given by the chief inspector of factories in pursuance of these regulations shall be given in writing, and may at any time be revoked by notice in writing signed by him.

Duties of occupier.

1. Every room in which casting, pasting, or lead burning is carried on shall contain at least 500 cubic feet of air space for each person employed therein, and in computing this air space, no height above 14 feet shall be taken into account.

These rooms and that in which the plates are formed shall be capable of thorough ventilation. They shall be provided with windows made to open.

2. Each of the following processes shall be carried on in such manner and under such conditions as to secure effectual separation from one another and from any other process.

(*a*) Manipulation of dry compounds of lead;
(*b*) Pasting;
(*c*) Formation and lead burning necessarily carried on therewith;
(*d*) Melting down of old plates.

Provided, That manipulation of dry compounds of lead carried on as in regulation 5 (*b*) need not be separated from pasting.

3. The floors of the rooms in which manipulation of dry compounds of lead or pasting is carried on shall be of cement or similar impervious material, and shall be kept constantly moist while work is being done.

The floors of these rooms shall be washed with a hose pipe daily.

4. Every melting pot shall be covered with a hood and shaft so arranged as to remove the fumes and hot air from the workrooms.

Lead ashes and old plates shall be kept in receptacles specially provided for the purpose.

5. Manipulation of dry compounds of lead in the mixing of the paste or other processes shall not be done except (*a*) in an apparatus so closed or so arranged with an exhaust draft as to prevent the escape of dust into the workroom; or (*b*) at a bench provided with (1) efficient exhaust draft and air guide so arranged as to draw the dust away from the worker, and (2) a grating on which each receptacle of the compound of lead in use at the time shall stand.

6. The benches at which pasting is done shall be covered with sheet lead or other impervious material, and shall have raised edges.

7. No woman, young person, or child shall be employed in the manipulation of dry compounds of lead or in pasting.

8. (*a*) A duly qualified medical practitioner (in these regulations referred to as the "appointed surgeon") who may be the certifying surgeon, shall be appointed by the occupier, such appointment unless held by the certifying surgeon to be subject to the approval of the chief inspector of factories.

(*b*) Every person employed in a lead process shall be examined once a month by the appointed surgeon, who shall have power to suspend from employment in any lead process.

(*c*) No person after such suspension shall be employed in a lead process without written sanction entered in the health register by the appointed surgeon. It shall be

[1] Factory and workshop acts. Dangerous and unhealthy industries. Regulations and Special Rules in force on 1st January, 1908. London, 1907, p. 7. [Regulations, dated November 21, 1903, made by the secretary of state for the manufacture of electric accumulators.]

sufficient compliance with this regulation for a written certificate to be given by the appointed surgeon and attached to the health register, such certificate to be replaced by a proper entry in the health register at the appointed surgeon's next visit.

(*d*) A health register in a form approved by the chief inspector of factories shall be kept, and shall contain a list of all persons employed in lead processes. The appointed surgeon will enter in the health register the dates and results of his examinations of the persons employed and particulars of any directions given by him. He shall on a prescribed form furnish to the chief inspector of factories on the 1st day of January in each year a list of the persons suspended by him during the previous year, the cause and duration of such suspension, and the number of examinations made.

The health register shall be produced at any time when required by H. M. inspectors of factories or by the certifying surgeon or by the appointed surgeon.

9. Overalls shall be provided for all persons employed in manipulating dry compounds of lead or in pasting.

The overalls shall be washed or renewed once every week.

10. The occupier shall provide and maintain—

(*a*) A cloakroom in which workers can deposit clothing put off during working hours. Separate and suitable arrangements shall be made for the storage of the overalls required in regulation 9.

(*b*) A dining room unless the factory is closed during meal hours.

11. No person shall be allowed to introduce, keep, prepare, or partake of any food, drink, or tobacco, in any room in which a lead process is carried on. Suitable provisions shall be made for the deposit of food brought by the workers.

This regulation shall not apply to any sanitary drink provided by the occupier and approved by the appointed surgeon.

12. The occupier shall provide and maintain for the use of the persons employed in lead processes a lavatory, with soap, nailbrushes, towels, and at least one lavatory basin for every five such persons. Each such basin shall be provided with a waste pipe, or the basins shall be placed on a trough fitted with a waste pipe. There shall be a constant supply of hot and cold water laid on to each basin.

Or, in the place of basins the occupier shall provide and maintain troughs of enamel or similar smooth impervious material, in good repair, of a total length of 2 feet for every five persons employed, fitted with waste pipes, and without plugs, with a sufficient supply of warm water constantly available.

The lavatory shall be kept thoroughly cleansed and shall be supplied with a sufficient quantity of clean towels once every day.

13. Before each meal and before the end of the day's work, at least 10 minutes, in addition to the regular meal times, shall be allowed for washing to each person who has been employed in the manipulation of dry compounds of lead or in pasting:

Provided, That if the lavatory accommodation specially reserved for such persons exceeds that required by regulation 12, the time allowance may be proportionately reduced, and that if there be one basin or 2 feet of trough for each such person this regulation shall not apply.

14. Sufficient bath accommodation shall be provided for all persons engaged in the manipulation of dry compounds of lead or in pasting, with hot and cold water laid on, and a sufficient supply of soap and towels.

This rule shall not apply if in consideration of the special circumstances of any particular case the chief inspector of factories approves the use of local public baths when conveniently near, under the conditions (if any) named in such approval.

15. The floors and benches of each workroom shall be thoroughly cleansed daily, at a time when no other work is being carried on in the room.

Duties of persons employed.

16. All persons employed in lead processes shall present themselves at the appointed times for examination by the appointed surgeon as provided in regulation 8.

No person after suspension shall work in a lead process, in any factory or workshop in which electric accumulators are manufactured, without written sanction entered in the health register by the appointed surgeon.

17. Every person employed in the manipulation of dry compounds of lead or in pasting shall wear the overalls provided under regulation 9. The overalls, when not being worn, and clothing put off during working hours, shall be deposited in the places provided under regulation 10.

18. No person shall introduce, keep, prepare, or partake of any food, drink (other than any sanitary drink provided by the occupier and approved by the appointed surgeon), or tobacco in any room in which a lead process is carried on.

19. No person employed in a lead process shall leave the premises or partake of meals without previously and carefully cleaning and washing the hands.

20. Every person employed in the manipulation of dry compounds of lead or in pasting shall take a bath at least once a week.

21. No person shall in any way interfere, without the concurrence of the occupier or manager, with the means and appliances provided for the removal of the dust or fumes, and for the carrying out of these regulations.

These regulations shall come into force on the 1st day of January, 1904.

A. AKERS-DOUGLAS,
One of His Majesty's Principal Secretaries of State.

HOME OFFICE, WHITEHALL,
21st November, 1903.

APPENDIX B.—GENERAL PROVISIONS OF THE FRENCH LAW GOVERNING THE MANUFACTURE OF ELECTRIC ACCUMULATORS.[1]

The kettles for melted lead must be kept in separate well-ventilated rooms, and efficient air exhausts must be provided.

Work with lead oxides must be done wet as far as possible. When this is not practicable, it must be carried on mechanically in a closed apparatus, or if the oxides must be handled, then the work must be done under a strong exhaust; if this is impossible, the workmen must be given respirators.

Mixing must be done in a separate room. No dry oxides may be handled in rooms where other work is done.

Oxides, dry or wet, must never be handled with bared hands. The employer must provide proper tools or impermeable gloves.

The tables on which the paste is handled must be covered with impermeable material and kept in good condition.

The floor must be of impermeable material and kept always damp. Tables, floor, and walls must be washed at least once a week.

Overalls must be provided and maintained in good condition.

No food is to be carried into the workroom. Separate dressing and wash rooms must be provided with sufficient washing facilities, soap; one clean towel a week for each man, and a locker for each man's clothes; a weekly warm bath, tub or shower, must be provided. For specified workers a daily warm bath must be provided.

Before employment a man must undergo a medical examination to show that he is not suffering from any disease which would make his employment in such work dangerous. At the end of the first month he must undergo a similar examination, and after that at three-month intervals. A medical register must be kept of all the men employed.

[1] Bulletin de l'Inspection du Travail et de l'Hygiene Industrielle, 1913, Nos. 5 and 6, pages 421 to 424.